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ABSTRACT

A study of differential brain hemisphere involvement in second language acquisition is reported. The study examined the idea that the right hemisphere is progressively more involved the later the second language is acquired. Various techniques for monitoring hemispheric functioning are described, especially the Evoked Potential (EP) technique. In this experiment, EPs in response to unilateral visual presentation of words in two languages were recorded in three groups of individuals, categorized according to the age at which they acquired the second language (infancy, childhood, and adolescence). The results did not support the popular notion of progressively greater right hemisphere involvement. (Author/MSE)

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Age of second language acquisition and
hemispheric asymmetry -- evidence from
evoked potentials

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Abstract

We review second language acquisition with reference to differential hemispheric involvement in such acquisition. In particular we examine the idea that the right hemisphere is progressively more involved the later the second language is acquired. Various techniques for monitoring hemispheric functioning are described, in particular the Evoked Potential (EP) technique. In the experiment described here EPs in response to unilateral visual presentation of words in two languages were recorded. There were three groups, categorized in terms of the age when the second language was acquired (infancy, childhood and adolescence). The results did not support the popular notion of progressively greater right hemisphere involvement.

1 Introduction : What is meant by hemispheric asymmetry?

On the face of it, the human body appears perfectly symmetrical. However, on closer examination, we find that there are many minor physical differences between the two sides of the body. Here we look at the differences between the two sides of the brain; particularly the functional differences related to language. The neurosciences often talk of functions being lateralised. The question posed is "What is the relative degree of competence, dominance or participation of the two sides of the brain in carrying out a particular function?". A function which is lateralised is one which is asymmetrically distributed in the brain.

As neuroscientists our reason for looking at second language acquisition was to discover the brain processes involved in acquiring and using a second language. Our reason for presenting this paper to a conference of this kind is that we felt the neurosciences might have something to offer the teacher. It should, in principle, be possible to design teaching programs that exploit the basic asymmetric functioning of the brain. Our results are inconclusive but will, we hope, be thought provoking.

2 Morphological asymmetries of the human brain

We won't consider in any detail the physical asymmetries of the brain but a brief review will be relevant. Many of the asymmetries are visible to the naked-eye. We find that the right hemisphere has more tissue and is heavier. Its frontal region is wider and extends further forward than the left. The left occipital pole is wider and protrudes more posteriorly and the anteroparietal and posterooccipital regions are generally larger on

the left.

Regions more specifically involved with language processing are also asymmetrical. Brocca's area, which has to do with language output is larger and has greater folding on the left. The Sylvian fissure is generally longer on the left before it bends upwards while the Sylvian point is generally higher on the right. These facts reflect the size of the temporal planum which constitutes a large part of Wernicke's region which has to do with the brain's phonological system. In 65 - 90% of the cases it is larger on the left (See Kolb and Wishaw, 1980; Bradshaw and Nettleson, 1983). No one has yet demonstrated that asymmetry of size is related to asymmetry of function. It is tempting to view the findings, especially those relating to language, as more than just coincidence. But how do we explain that other primates also show these anatomical asymmetries?

Perhaps these asymmetries of the language areas support cognitive processes necessary for language functioning. Two examples are the temporal sequencing of movements and an advanced ability to discriminate rapidly changing frequencies (Bradshaw and Nettleson, 1983).

3 Studies of functional asymmetry of the brain

The functional asymmetries of the brain have been studied using a number of techniques. Clinical and invasive studies have included (a) individuals having brain damage (including commissurotomy and hemispherectomy), (b) anesthetic injected into the major blood flow to either side of the brain, and (c) unilateral electroconvulsive shock in cases of psychiatric disorders. Experimental non-invasive techniques will

be considered in greater detail since they seem to be the most common techniques employed on normal populations and are also partly used in the present research.

3.1 Dichotic listening

This technique (Kimura, 1961) exploits fact that the left ear has major input to the right hemisphere and the right ear has major input to the left hemisphere. Thus, if information arriving at a given ear is relevant to the processing capacities of the corresponding hemisphere, then it should be perceived better. Indeed, it is found that the right ear (which feeds into the left hemisphere) is generally more efficient at perceiving verbal stimuli.

3.2 Visual half-fields

The visual half-field technique (McKeever and Huling, 1971), used in the present experiment, relies on the fact that the two visual fields (not the two eyes) project to the opposite hemispheres. Thus, if the individual fixates on a particular point in space, things appearing to the right of it (right visual field, RVF) project to the left hemisphere while things to the left (left visual field, LVF) project to the right hemisphere. If the stimulus is projected fast enough so the individual cannot move his eyes, then the stimulus will arrive in just one (i.e. the opposite) side of the brain.

3.3 Electrical recordings

The electrical recording technique, also used in the present experiment,

relies on the fact that when the brain is functioning, it creates electrical fields which, with sensitive equipment, can be detected and recorded directly from the scalp. The technique we used is called the average evoked potential technique. The idea behind it is that there is a relatively invariant response by the brain to a given stimulus under a give set of conditions. A stimulus is presented, and the response of the brain is recorded from electrodes placed on the scalp. The problem with this is that the ongoing background electrical activity of the brain (noise) swamps the evoked response (signal). In other words, there is a low signal to noise ratio. However, if we average across many stimulations then the random background noise cancels out leaving the evoked potential to emerge more and more strongly. From the size of the signal at different points we can find out where different functions are located in the brain.

4 Language asymmetries

The cerebral hemispheres are functionally asymmetrical in a number of ways but we will address only the linguistic and paralinguistic differences. The overwhelming evidence supports lateralisation of language in the left hemisphere, at least in most adults. Just a few years ago it was thought that the right hemisphere is completely devoid of linguistic ability, but we now know that this view has to be modified.

4.1 Distribution of language in the left hemisphere

The effects of brain damage and electrical stimulation of the brain have served to identify the language areas. Penfield and Roberts (1959) showed

that stimulation within these areas produces temporary disruption of speech while damage in this area may produce permanent impairment of language functions (Luria, 1966, 1973). The critical area is confined primarily to the lateral surfaces of the left hemisphere and includes the auditory receptive areas and adjacent zones as well as the inferior Rolandic and pre-Rolandic areas (which control the articulatory organs). Within these areas, phonological, syntactic and lexical functions can be found (Marin, 1979); the left hemisphere is almost entirely dominant for these functions.

4.2 Right hemisphere language functions

Indications are that right hemisphere language functions lag way behind the left hemisphere. Oral language is entirely absent. However, Zaidel (1978) has shown that the right hemisphere may function syntactically at the 4-6 year level. Further, lexical abilities are present so that on a picture vocabulary test, left hemispherectomy patients were able to function at an 8-16 year level. A dichotic listening paradigm showed that the right hemisphere was less able to identify abstract nouns than the left hemisphere (McFarland et al., 1978). Commissurotomed patients show an ability to comprehend words presented to the right hemisphere as long as they are rather concrete nouns, adjectives and descriptive phrases. However, they are poor at comprehending verbs and abstract nouns (Marin et al., 1979). It would appear that the nature of right hemisphere language is limited to a rather impoverished lexicon.

4.3 Right hemisphere paralinguistic functions

It is apparent that the left hemisphere is dominant for the core language

functions such as phonology, syntax and semantics. However other functions, called paralinguistic functions, add something to language. These include intonation, emotional tone, context, inference and connotation. Patients with right hemisphere lesions are impaired in producing and perceiving the correct emotional tone of linguistic utterances, react inappropriately to humorous material, interpret metaphors incorrectly, have difficulty in solving subtle sentences, anagrams, and have a poor appreciation of antonymic contrasts, actor object relations, and connotative aspects of pictures (Moscovitch, 1983). Patients with right hemisphere damage seem to have no difficulty comprehending individual sentences but they do have difficulty relating a sentence to a larger context, understanding its emotional connotations and drawing the proper inferences from it. Without the right hemisphere, communication, in its broadest sense, may be impoverished.

4.3.1 Intonation and music

There is strong evidence to suggest that speech intonation and music abilities are largely supported by the right hemisphere. Even though left hemisphere damage may cause severe disruption of speech, intonation and singing may remain relatively intact. Conversely, right hemisphere damage has been shown to cause a lack of speech intonation and some patients even lose the ability to laugh and cry (Borod et al. 1983). Likewise, right temporal lobectomy impairs musical discrimination (Milner, 1962) and injections of anesthetic into the blood supply of the right hemisphere depresses singing but not speech (Bogen and Gordon 1971). Using the dichotic listening technique has revealed a left ear advantage for emotional tone of natural speech (Haggard and Parkinson, 1971) and the

identification of melody (Kimura, 1964).

This right hemisphere ability for intonation and musical processing has been exploited in speech therapy with those having aphasia from left hemisphere damage. Melodic intonation therapy accentuates the intonation of phrases and sentences or patients may be taught phrases in song. The song is then gradually deemphasised (Eastabrook, 1983).

4.3.2 Emotion

We have already seen that the right hemisphere appears to be concerned with judging the emotional tone of speech. Damage to the right parietal region may impair the identification and production of both negative and positive emotions even though they are conveyed verbally (Heilman, Scholes, and Watson, 1975 in Moscovitch, 1984). There is also good evidence that emotional expressions are better experienced by the right hemisphere when they are presented in the split-field mode (Ley and Bryden, 1979). An interesting finding is that the left side of the face is often most expressive of emotion (Moscovitch and Olds, 1982).

4.3.3 Metaphor and Humor

Much of language is figurative. It has been found that individuals with right brain damage tend to perceive things more literally than control subjects (Winner and Gardener, 1977).

Likewise, right brain damaged individuals find difficulty in appreciating humour. They do not appreciate cartoon drawings often missing the point (Gardener et al., 1975) and do not appreciate jokes. The argument is

that they do not integrate or perceive details in context and so miss the punch line.

4.3.4 Imagery

There is strong evidence to suggest that the right hemisphere is specialised in visual imagery (Humphrey and Zangwill, 1951; Penfield and Perot, 1963; Bryden and Ley, 1983; Robins and McAdam, 1974; Ley, 1982). There are also suggestions that visual imagery may be strongly related to some language functions. Imagable concrete words are more easily recognised when presented to the right hemisphere. There might be quicker access to the right hemisphere lexicon since no phonological encoding would take place (Bradshaw, 1980).

Imagery is a successful mnemonic device which helps verbal recall (see Fitch-West, 1983). Concrete pictures are highly efficient at arousing both the visual and the verbal codes (Fitch-West, 1983) and it does not take much imagination to realise how concrete pictures and encouragement to form images could help second language acquisition. Indeed, concrete pictures have been used for the treatment of aphasics.

The point to remember is that while the left hemisphere is clearly concerned with core linguistic functions, the right hemisphere, with its paralinguistic functions, probably makes a real contribution to linguistic performance.

5 A reexamination of the nature of hemispheric differences

We have noted that brain functions tend to be asymmetrically distributed

between the two hemispheres. However, there has been much discussion about fundamental functions which might distinguish the two hemispheres. It is popular, for example, to talk of the two hemispheres as having different cognitive styles usually expressed as dichotomies such as verbal vs non-verbal, diffuse vs focal, serial vs parallel and analytic vs wholistic. These dichotomies probably miss the point. It is not so much a question of which hemisphere does the processing as the kind of processing done by each.

Thus, verbal information may be processed by both the left and right hemispheres. The left hemisphere might have to do with analysing the meaning of words and sentences while the right hemisphere concerns itself with the meaning of words and sentences in context.

A good example to demonstrate this point is facial recognition. This is supposed to be a right hemisphere function because the best strategy is to perceive it as a whole. However, whether the left or right hemisphere is dominant in perceiving faces depends on the strategies used. Ross and Turkenitz (in Segalowitz, 1983) presented faces for identification in either the left or right visual fields. Some individuals were better in the left visual field some were better in the right. In follow-up experiments it was found that those people who were better in the right visual field (left hemisphere) were disrupted by obscuring details on the face such as moustache, eyebrows, and noses. Those who were better in the left visual field (right hemisphere) were disrupted by global changes made to the faces such as inverting the face. It appears, then, that the left hemisphere is sensitive to details or specialises in analysing a stimulus configuration while the right hemisphere is sensitive to the overall pattern or specialises in wholistic processing.

Whether the descriptive terms used to differentiate hemisphere functioning are valid or not, there is general support for the fact that the two hemispheres go about things in different ways. In any given situation, both hemispheres are usually operative and contribute to the task at hand. However, under certain circumstances a given strategy may be most appropriate and one or the other hemisphere will tend to dominate.

We are now in a position to comment on the theory and research in the neuropsychology of bilingualism.

6 Theory and research in the neuropsychology of bilingualism

A large part of the neuropsychological research into bilingualism has been concerned with the cerebral organisation or representation of two or more languages in the brain. The question frequently asked about polyglots is whether two or more languages occupy, or are mediated by, the same or different parts of the brain. Scoval (1969) for example, maintains that we learn a second language in an anatomically different way from that in which we learn our first language. He points out that in first language learning associations are made mainly between object and name whereas in second language learning the key process is to translate from one language to the other without reference to the actual world of objects. Lambert and Fillenbaum (1959) propose compound and coordinate bilinguals. In a compound bilingual the two languages are so well integrated as to be indistinguishable. In a coordinate bilingual the two languages are maintained as distinct entities using two separate brain systems. There is some controversy about which type actually occurs, or whether they both do.

In addressing this problem there are both clinical and experimental approaches to be considered.

6.1 Clinical Evidence

The clinical approach has largely looked at polyglot aphasics. (Aphasia is a generic term for language disturbances resulting from damage to the language areas of the brain). Differential impairment and/or recovery would suggest that two languages are dependent on different brain structures. Equivalent impairment and/or recovery would be evidence for identical brain systems.

There is evidence that language dissociation does occur among bilingual aphasics. Estimates of the incidence of these differential aphasic patterns are 58% for Albert and Obler and 45% for Paradis (1977). However, Galloway (1980) and Vaid and Genesee (1980) point out that these estimates are probably inflated because it is the unusual and interesting cases that get reported. Studies on unselected cases produce more modest figures. Charlton (1964) reports 2 out of 9 cases and Nair and Virmani (1973) report 2 in 33 cases.

More specific hypotheses about bilingual brain organisation have been suggested. These predict greater right lateralisation of language or less complete left lateralisation. Put differently these propose that at least one language is represented bilaterally (Paradis, 1977; Obler et al., 1982; Sussman et al. 1982).

If language in bilinguals is less left lateralised than in monolinguals

then one would expect to find a higher frequency of language impairment in bilinguals with right sided brain damage. This tends to be the case. Polyglot aphasics have a higher incidence of right hemispheric damage compared to monoglots. Galloway (1982) taking a retrospective look at 102 polyglot aphasics found 15% had right sided lesions whereas only 2% of monolingual controls manifested right side lesions.

Vaid and Genesee (1982) are not convinced. The differential organisation of language in the brains of polyglots is probably not the rule but is dependent on the effects of a number of factors such as language specific effects, acquisitional factors and affective factors.

6.2 Experimental evidence

We now turn to the experimental evidence for greater right hemisphere involvement in second language processing. Once again the picture is not a simple one -- conclusions have to be qualified in terms of a number of variables and their interactions.

We have already noted the theories on distinctive hemisphere functioning. As before, we conclude that the hemispheres are distinct, not because of the type of stimuli they process (eg. verbal vs non-verbal), but because of the way (e.g. wholistic vs analytic) in which information is processed.

Thus, the same information can be processed by both hemispheres in different ways.

Language cannot be seen as a discrete process in the left hemisphere alone. Rather, language consists of many interrelated cognitive processes -- some performed by the left and some by the right hemisphere. We should

not be so concerned with whether the two languages of a bilingual are processed by different hemispheres. We should ask instead what hemisphere would be brought into operation according to the demands placed on the individual.

The important factors that determine hemisphere involvement have been well and comprehensively discussed by Galloway (1982), Obler (1978,1981) and Vaid and Genesee (1982) and include (a) language specific factors, (b) acquisition factors (c) cognitive strategy effects, (d) proficiency factors and (e) sociolinguistic factors among others.

In the present study we are interested in some of the factors that affect how a second language is acquired.

6.2.1 Age of acquisition

During the early stages of development the brain is "plastic", i.e. it has the ability to recover a function after damage has caused its loss. The younger the child, the greater the recovery after damage to the left hemisphere. After puberty there is little recovery (though there may be reduced plasticity from as young as five years).

If two languages are co-acquired in infancy then both probably follow the same course that a single language would at that age, i.e. bilateral representation followed by progressive lateralisation to the left hemisphere. A second language acquired after the loss of cerebral plasticity will be subject to different cerebral organisation. Both Galloway (1982) and Vaid and Genesee (1982) suggest that second language acquisition will involve different processing strategies at different

stages of development. Early in life left hemisphere type strategies would tend to predominate. Later, however, with reduced plasticity and the development of paralinguistic skills, there would be a bias towards right hemisphere strategies.

A study by Genesee et al. (1978) used evoked potential measures. Subjects responded to taped stimuli by pressing a button. In this study, the balanced bilinguals were divided into three groups on the basis of age of second language acquisition. When those who had acquired the second language during adolescence listened to either language, they showed an earlier N100 peak in the right hemisphere than in the left hemisphere. Those who had learned the second language in infancy or childhood showed a faster N100 peak in the left hemisphere in either language condition. This difference implied that the adolescent learners employed right hemisphere strategies when they processed language in this identification task.

Obler (1981) suggests that a simple proficiency difference between the groups (adolescent learners less proficient) could have accounted for the findings.

Vaid and Lambert (1979) replicated the findings of Genesee et al. (1978) showing more right hemisphere involvement the later the second language was acquired.

It should be noted, however, that there is also evidence against differential involvement of the two hemispheres (see Vaid and Genesee, 1980) as a function of age of acquisition.

6.2.2 Stage of acquisition (proficiency)

Early during second language acquisition, the cognitive strategy is probably right hemisphere related but later gives way to left dominant strategy. The speech production of beginning second language learners, adults as well as children, consists of highly contextualised formulaic utterances. The right hemisphere is quite capable of overlearned verbal responses such as days of the week and swearing (we know this from aphasics with left hemisphere damage). If learners of a second language (whether early or late) do so in a formal setting, with the emphasis on rote learning, the right hemisphere is likely to be involved.

Speech comprehension relies on prosodic rather than phonetic features: pragmatic rather than syntactic information and content rather than function words (see Vaid and Genesee, 1980). Further, early learners are known to understand by recognising a few words and guessing the rest. This ability to discern meaning from context both linguistic and non-linguistic is known to be within the capabilities of the right hemisphere.

Gaziel et al. (1977) tested right handed Israeli school children from the seventh, ninth and eleventh grades. Hebrew was the native tongue and learning of English started in the fifth grade. English and Hebrew words were shown in the left or right visual fields. Most subjects revealed a RVF effect in the Hebrew condition while in the English condition a LVF effect emerged, most evident in the seventh grade subjects and diminishing in the higher grades.

There are four studies commented on by Vaid and Genesee (1980) that

suggest that right hemispheric involvement may persist even in the final stages of second language acquisition (Genesee et al., 1978; Gordon, 1980; Vaid and Lambert, 1979).

However, not all the evidence supports the proficiency or stage of acquisition hypothesis (Gordon, 1980; Kershner and Jeng, 1972; Hardyck, Tzeng & Wang, 1978).

Probably one of the major points to be made here is that after plasticity is lost, the general tendency to use the right hemisphere early in second language acquisition may persist since there may be an inability to transfer to a left hemisphere strategy.

6.2.3 Manner of acquisition

We need to distinguish between formal and informal language learning. The formal mode emphasises the structure of language and its rules. Such a method usually involves rule specification and drilling. The informal mode uses naturalistic communication in which the individual is more concerned with content rather than form. When the formal mode of instruction is being used there is continual monitoring or evaluation of the process according to learned rules. This is an analytic process which is more left hemisphere related. When the informal mode of learning is being used, contextual information, intonation, facial expression, and so forth are all being used which tends to be a wholistic process and right hemisphere related.

Kotik (1979 in Segalowitz, 1983) compared Russian-Estonian bilinguals on a

dichotic task in both languages. The Estonians showed a larger left hemisphere advantage than the Russians. The difference is in the learning. The Russians learned Estonian in everyday circumstances. The Estonians learned Russian only in school.

Gordon (1980) using a dichotic listening procedure showed that Hebrew speakers who learned English as a foreign language in Israel did not show reduced language laterality. Hebrew speakers who had spent many years abroad in English-speaking countries showed lower laterality scores.

There are of course other factors which affect the lateralisation of languages but these will not be considered in detail.

6.2.4 Language specific effects

By this we mean structures inherent in the languages of the bilingual which might induce, or be conducive to right hemispheric involvement. Reading scan: Reading scan direction varies between languages. Scan is found to be an important factor in speed of processing of information fed to the right or left visual field. For example, for left to right scanning, information on the right will be perceived faster and hence is confounded with laterality factors. For right to left scanning as in Yiddish or Hebrew, information in the left visual field will be perceived faster. It is found however, that reading scan alone cannot account for laterality differences (See Obler, 1981 p.55).

Rogers et al. (1977) suggest that the Hopi language is closely associated with the perceptual world whereas English is not. They suggested that Hopi elicits appositional thought whereas English elicits propositional

thought. Thus, Hopi should be more related to right hemisphere functioning and English to the left hemisphere. They monitored the EEG of Hopi/English bilinguals while they listened to taped folk tales in Hopi and English. Greater right hemisphere suppression of alpha activity was obtained for Hopi than English.

Vowel characteristics of the language are also supposed to affect hemispheric involvement. In Japanese and Polynesian languages vowel sounds can be legal words and would therefore be processed in the left hemisphere. Since vowel sounds tend to be just part of most European language words, they may be processed by the right hemisphere (see Tsunoda, 1971 in Vaid and Genesee, 1980). Note, however, if the vowel sounds are reduced in length so that they are equal to those normally found in speech, then a left hemisphere dominance resumes probably because the brain now interprets them as part of the language system (Darwin, 1975).

Two additional factors we should consider are attitude toward second language learning and gender.

6.2.5 Attitude

When polyglot aphasics show differential recovery of their languages, this may be the result of associated positive and negative affect associated with the languages. Research with neurologically intact individuals has demonstrated the importance of affective variables; in particular, positive attitudes towards second language learning. See Vaid and Genesee (1980) for a review.

6.2.6 Sex

Sex has received little attention in the neuropsychology of bilingualism although Gordon (1980) and Vaid and Lambert (1979) have emphasised its importance. There is evidence for differences in morphology of brain structure between the sexes (Witelson and Pallie, 1973). Wada, Clarke and Hamm (1975) indicated that the planum temporalum is bigger on the right in the female than the male suggesting less asymmetry in the female.

This accords with the functional findings that females are less lateralised than males (Hughes, 1982; Tucker, 1976) suggesting bilateral representation of most functions. In bilinguals, females appeared to rely less than males on the left hemisphere in analysing the meaning of French and English words (Gordon, 1980; Vaid and Lambert, 1978). It is possible, therefore, that females may show enhanced right hemisphere involvement in the acquisition and use of their second language.

7 Recapitulation

The material we have reviewed so far clearly demonstrates that the left hemisphere is specialised in linguistic functions while the right hemisphere is more concerned with the so-called paralinguistic functions. The individual faced with acquiring a second language may find that he must revert to these non-lingual skills in order to discern what is being said to him, or what he reads. In other words, he may rely on the non-linguistic context especially if the language is acquired in the informal setting. Such skills use the linguistic context, intonation, facial expression, and the integration of all of these simultaneously. Right hemispheric involvement might therefore be part and parcel of second

language acquisition. Since females show less hemispheric lateralisation than males anyway, perhaps this sex difference may be enhanced. However, as proficiency increases the individual reverts to regular linguistic skills.

We have also noted that some individuals may never lose the tendency to use the right hemisphere when using a second language. These individuals have probably acquired their second language after puberty. Since this coincides with the loss of cerebral plasticity, perhaps the reason for persistence of the right hemisphere involvement is the brain finds it difficult to incorporate the language specific characteristics of the second language into the existing language system. On the other hand, perhaps once such right hemisphere skills are acquired and used it may simply be a case of not being able to kick the habit.

8 How could neuropsychology contribute to second language teaching?

It seems that the right hemisphere becomes involved in the acquisition of a second language. This interests us as neuropsychologists, but more generally we hope that it might have spin-offs for teaching and of course this is why we have presented this paper in this company.

The right hemisphere is responsible for many of the paralinguistic functions that might make sense of a foreign language especially in the early stages of acquisition. How would one go about "heightening" right hemisphere involvement in second language acquisition? Perhaps one could purposively incorporate the type of stimulation, known to affect the right hemisphere, in one's teaching. Not only would this involve direct use of

a particular function but perhaps it would prime the right hemisphere in general in the learning situation. In answering this question one may consider a suggestion by Fitch-West (1983) in a treatment paradigm for aphasics.

"The answer ... is to use naturalistic, conversational settings that are highly redundant and have rich contexts so that the patient is able to extract as much as possible from the nonlinguistic context itself".

And further:

"Rather, the patient can call upon holistic processing strategies which will help him gain an intuitive grasp of what is happening. As ... (it is the right) ... hemisphere that can recognise melodic contours, facial expressions, emotions and the like, it would be helpful to be extraordinarily expressive vocally and facially in this naturalistic setting" (p.217).

Imagery, which we have already mentioned, must not be ignored. This is a right hemisphere function, and it may have a significant role to play in facilitating storage of linguistic information.

It may be that your own research into second language teaching has independently shown that some of these techniques are worthwhile in which case we hope that we have served to validate some of your findings.

9 An experiment on hemispheric processing of words from different languages

9.1 Aim

Our experiment was designed mainly to look at the effect of Age of Acquisition and Sex on the differential involvement of the two hemispheres in second language acquisition.

We wanted to rectify the failure of Genesee et al. (1978) to control the sex variable. To do this we included Sex as a relevant independent variable in our study. In addition, we felt we should take the opportunity to investigate the spatial and temporal order of language processing in bilinguals. As mentioned earlier in this paper, evoked potentials tell us something about the temporal order of information processing and its location in the nervous system. In other words, a stimulus gives rise to a series of voltage "bumps" which represent the temporal order of processing. Further, the shape and size of these bumps may vary with respect to location in the nervous system (see Figure 2).

The languages we used were English and Afrikaans - both official languages in South Africa and compulsory subjects in the school curriculum. Of interest to us is the fact that some words look the same in the two languages but differ in meaning (e.g. "loop" is an English word, but it is also an Afrikaans word, and in that language it means "walk"). The only way, therefore, that such words can access meaning is by the subject knowing which language is current either by context or being told as much. Since some evoked potentials are sensitive to the physical structure of the stimulus, we felt that by using such ambiguous words the differences

that would arise in the evoked potentials would be due only to their "accessed" meanings.

Thus, if a particular hemisphere is alerted or "primed", by telling the subject which language is current, then we might expect the right hemisphere to show greater response to the second language while the opposite should be true for the first language. Since early processing of information in the nervous system is probably of simple physical features of the stimulus such as shape or size (Hillyard and Woods, 1979; John, 1977), we might expect that there would be very little difference between the languages using ambiguous stimuli. On the other hand, since the appropriate hemisphere is primed, it is possible that even at the earliest levels of processing language differences may be found.

9.2 Subjects

Our subjects were 18 young adult bilinguals (somewhat more fluent in English than Afrikaans). They were divided, on the basis of their age at the time of second language acquisition, into three groups of six: (a) "infant bilinguals" who acquired both languages at the same time in infancy, (b) "childhood bilinguals" who acquired Afrikaans between the ages of 6 and 12 years and (c) "adolescent bilinguals" who acquired Afrikaans after the age of 13 years.

9.3 Apparatus

Stimuli were presented on a visual display unit (VDU). The evoked potentials were recorded on a Medelec ER94 averager interfaced to a BBC microcomputer. The microcomputer controlled the sequence of trials,

generated and displayed the words and stored the evoked potential traces. The arrangement is depicted in Figure 1.

Insert Figure 1 about here

9.4 Stimulus Material

There were eight common English four-letter words and their Afrikaans translations. These were unambiguous across languages in the sense that none of them would have been a legal word in the other language. A further eight were ambiguous across languages in the sense that they could have been English or Afrikaans (though they would have different meanings in those two languages). See Table 1.

Insert Table 1 about here

9.5 Procedure

Four active electrodes were placed on the scalp in standardised positions (O1, O2, P3, P4). Two electrodes were placed on each hemisphere one at the lower end and one at the higher end of the assumed information processing system. Recordings were taken from all 4 electrodes simultaneously under four different experimental conditions. In this way, 16 separate averaged traces were obtained and stored on floppy disc for latter manipulation and analysis.

The subject sat 50cm from the VDU fixating a point in the middle of the screen. Words were flashed for 200 milliseconds (msec) to the left or to the right of this fixation point, in random order. For each block of word presentations the subject was told whether the stimuli were to be English or Afrikaans but not whether they were ambiguous or not. The subject responded by saying the word as it was presented. A voice-activated switch initiated the cycle for the next word.

To summarize, each block used words in one of the two languages. Eight of the words were unambiguous and eight were ambiguous. Each word was presented three times in each hemifield. These combinations were presented in random order and yielded 96 presentations per block.

9.6 Results and discussion

As a start it might be interesting to consider briefly one of the less central findings of the present study. It is not new but it certainly suggests that there is a marked difference in the proficiency of brains belonging to the different sexes. Figure 2 clearly demonstrates that females not only respond more intensely to verbal stimuli but also process verbal stimuli much faster than males. It is pleasing to note that the behavioural findings have a cerebral counterpart.

Insert Figure 2 about here

The results are categorised under the headings of ambiguous and unambiguous stimuli; each of these categories are further divided using different measurements, namely, measurements on relatively early (N150) and relatively late (P250) evoked potential components. We considered only amplitude measurements. The early component was taken from N150 to P250 while the late component was taken from P250 to the highest subsequent negative point. We are also considering only the parietal locations of the brain. (Key: N or negative deflections are, by convention, upward. P or positive deflections are downward. The numbers refer to milliseconds. See Figure 2 which shows a strong P250 component for both men and women).

At this stage it will be well to remind you explicitly that the major question asked in this study was whether age of acquisition of a second language is significant in determining the extent of right hemisphere involvement in processing the second language.

9.6.1 Ambiguous words

The early components of the evoked potential are said to involve the processing of the superficial features of the stimulus (Hillyard and Woods, 1979). It might be that ambiguous words that do not differ superficially might be treated no differently in English and Afrikaans. On the other hand, since these words were presented in the context of a particular language and the subject was told what language to expect, the appropriate side of the brain might have been primed to respond to a given language.

Figure 3(a) shows that there is no substantial relationship between age of

acquisition of Afrikaans and responsiveness to Afrikaans in the right hemisphere. Our hypothesis was therefore not supported. It is apparent, however, that there are definite group differences. Indeed, a three way analysis of variance (ANOVA) showed that these differences were statistically significant on the left ($p=0.02$) and on the right ($p=0.045$). Such differences between the groups in either hemisphere irrespective of language are not easily explained but we might speculate. The tendency for Group 3, the adolescent learners, to show greater responsiveness to both languages may have something to do with lower proficiency in the second language and it may be this, rather than the age of acquisition, that gives rise to the effect. We address this issue later.

Insert Figure 3 about here

The late components are said to involve the processing of deeper features of the stimulus such as meaning (Hillyard and Wood, 1979). Here we find a significant lateralised effect in relation to age of acquisition; see Figure 3(b). The right hemisphere clearly showed more intense processing of English words in the adolescent learners but more intense processing of Afrikaans in the infant learners. A three-way ANOVA showed that this interaction between language and group was significant ($p=0.044$). This completely contradicts the predicted outcome and its explanation would be sheer speculation at this stage. There were no group effects similar to those found in relation to the early component. This despite the fact that ambiguous words differed in meaning (depending on their context).

9.6.2 Unambiguous words

The presentation of unambiguous words differed from that of the ambiguous words because the subject was not only primed about which language was current but there were also clear surface cues characteristic of the given language.

With respect to early components Figure 3(c) shows no clear relationship between age of second language acquisition and the tendency to use the right hemisphere for second language processing. However, once again there are definite group differences. Group 3, the adolescent learners, show greater responsiveness to both languages in both sides of the brain. Indeed, a three-way ANOVA revealed a significant group effect on the left ($p=0.058$) and on the right ($p=0.035$). The fact that this occurs in both hemispheres suggests that the adolescent learners are generally more responsive. Once again this could be due to a proficiency factor.

Looking at the late components in Figure 3(d), we find no significant relationship between age of acquisition, language and most intense hemisphere processing. Neither were there any significant group effects. However from Figure 3(e) we see there is a greater responsiveness by females in the right hemisphere for both languages ($p=0.035$). This did not hold for the left hemisphere. The fact that females showed greater responsiveness than males in the right hemisphere is not surprising since it is widely accepted that females are less lateralised for language than males. Though females have greater right hemisphere linguistic ability than males, it is still the less proficient hemisphere for language processing. This reduced proficiency may force a disproportionate level of resource to be allocated to the right hemisphere, giving rise to the

result above.

Note however, that Vaid and Lambert (1979) have shown that females prefer to process meaning in the right hemisphere rather than the left leading them to conclude that there is an "... intriguing possibility that the meaning is processed more efficiently in the right hemisphere for this group" (p. 104).

The conclusions from all of this must be tentative. There is no supporting evidence for greater right hemisphere involvement in second language processing. There are indications, however, that the adolescent learners allocated more processing resources to both languages possibly because they were less proficient and put more effort into the task as a whole. We have also noted that females show a greater responsiveness in the right hemisphere possibly related to its ability to process language, though less proficiently than the left hemisphere.

Finally, we feel that there are two major criticisms of our experiment.

- i) Our groups were not balanced. The adolescent group had used the second language for less time than the others and were probably less proficient. This led to a bias in the effort put into processing language in general in the present circumstances. The evoked potentials we have considered are known to vary in relation to the magnitude of resources allocated to the stimulus evoking them. It might be expected that relatively unfamiliar stimuli may require greater resources than familiar ones. It is our contention that the adolescent learners were less proficient at Afrikaans than the other groups and therefore required greater neural resources for processing

language in general in the present setting.

- ii) The experimental conditions were so artificial that the usual paralinguistic functions were probably not invoked as they might have been in a more naturalistic setting. Thus, the visual presentation within an obvious linguistic and paralinguistic context may have failed to bring the right hemisphere functions into operation. A design which purposely included a number of paralinguistic cues might have provided better support for the present hypothesis. Spoken stimuli with language characteristic prosodic cues, placed in a natural linguistic context such as a sentence, might be the sort of experimental setting which would lead to the predicted results.

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Table 1

Stimulus words used in the experiment

(Note: the ambiguous words are not ambiguous within a language; rather they have meanings in both English and Afrikaans)

Unambiguous words		Ambiguous words
English	Afrikaans	
take	neem	gang
read	lees	kind
show	toon	stem
side	kant	slim
city	stad	bang
turn	keer	held
wood	hout	loop
cold	koud	skip

Figure Captions

Figure 1

The experimental setup. The computer displayed a word on the VDU and triggered the averager. The participant spoke the word which sequenced in the next presentation.

Figure 2

Average evoked potentials for male and female participants. The amplitude is in arbitrary units, with a peak to trough displacement of about 100 microvolts. The female trace shows evidence of more rapid response to stimulation of the order of 25-30 msec.

Figure 3

Amplitude measures of EPs in response to words in the two languages. Panels (a) through (d) show group by hemisphere differences. (a) and (b) show results for unambiguous words; (c) and (d) for ambiguous words. (a) and (c) are early component (i.e. N150) amplitudes; (b) and (d) are late component (i.e. P250) amplitudes. Panel (e) shows sex by hemisphere differences for unambiguous words, late component.





